MARKED-UP VERSION OF ENGLISH TRANSLATION OF INTERNATIONAL APPLICATION AS ORIGINALLY FILED

~~DESCRIPTION~~

~~OPTICAL~~Attorney Docket No. 38195.79

LENS MATERIAL, OPTICAL ELECTRONIC COMPONENT AND OPTICAL ELECTRONIC DEVICE

~~Technical~~BACKGROUND OF THE INVENTION

1. Field of the Invention

~~[0001]~~

[0001] —The present invention relates to ~~an optical~~ a lens material, an optical electronic component and an optical electronic device, and in particular, ~~an optical~~ to a lens material ~~of which~~ having a reduced amount of birefringence ~~is reduced, an~~ , and optical electronic component ~~therewith~~including the same, and an optical electronic device ~~therewith~~including the same.

~~Background~~2. Description of the Related Art

~~[0002]~~

[0002] —As optical materials for an optical system, glass, plastics, synthesized quartz, calcium fluoride and ~~so on~~ other suitable materials are known.

[0003] ~~—The glass~~Glass and plastics ~~are~~have low ~~in the~~

refractive indexes. For instance, a glass lens ~~that uses glass~~ has ~~the~~a refractive index of substantially 1.5 (see, for ~~instance, patent literature 1).~~example, JP No. 2859621 (Patent Literature 1)). When lenses having the same focal distance are ~~tried to manufacture, for~~ manufactured using the glass, a curvature radius of the lens ~~has to~~must be ~~made smaller.~~decreased. That is, when the ~~material~~glass is used, ~~a~~ the thickness of the lens ~~becomes thicker; accordingly,~~ increases. Accordingly, miniaturization and thinning of the lens are difficult.

[0004] Furthermore, ~~in the~~ optical glasses~~,~~ made of materials having refractive indexes of ~~which are 1~~substantially 1.7 to 2.0 ~~as well~~ have been developed. However, there is a problem in that ~~since the larger~~as the refractive index ~~is~~increases, the ~~stronger the~~ coloring ~~is,~~of the lens increases and the light transmittance in a short wavelength region (corresponding to a wavelength from blue to green) in the visible light region ~~tends to be deteriorated~~deteriorates.

[0005] On the other hand, ~~as to the plastics lens~~with plastic lenses, a complicated shape can be ~~cheaply and readily~~inexpensively and easily molded. However, there is a problem in that, since ~~a~~ the volume ~~thereof largely~~of the lens greatly varies ~~under the influence~~as a result of ~~the~~ environmental ~~variation~~variations, such as temperature and

humidity, the refractive index tends to vary~~ to result in causing variation~~, which causes variations in the focal distance (~~for instance, non-patent literature 1~~see, for example, S. Nagata, ZUKAI RENDU GA WAKARU HON, pp 56-59, (January 20, 2003), First edition, Third printing (NIPPON JITSUGYOU SHUPPAN SHA) (Non-patent Literature 1)).

~~[0003]~~

[0006] ~~Separately from the foregoing materials~~In addition, as an optical material for optical elements for wavelength conversion, optical diffraction, phase conjugate mirror and ~~so on~~other properties, single crystals, such as lithium niobate and lithium tantalate, are known. The optical materials, ~~having the~~ which have refractive ~~index~~indexes of at least 2.0~~ or more, have possibility of realizing miniaturization~~, can be miniaturized and ~~thinning.~~thinned. However, the single crystals, being a uniaxial crystal, have different refractive indexes for ordinary light and extraordinary light~~; accordingly,~~ . Accordingly, there is a problem in that ~~the~~ birefringence is caused and ~~the~~ doubling results. As a result, the single crystals could not be used in a lens and optical system.

~~[0004]~~

[0007] There is a proposal ~~of an~~ for optical pickup ~~lens~~

lenses for magnetic optical disks, DVDs (Digital Versatile Disk) and ~~so on~~other devices, in which lithium tantalate that generates the birefringence is used (see, for ~~instance, patent literature 2).~~example, JP-A No. 11-312331 (Patent Literature 2)). However, ~~to a crystal optical axis of a single crystal,~~ a light incidence axis (light incidence direction) has to be set at an angle of at least 0° ~~or more~~ with respect to a crystal optical axis of a single crystal, (in particular, a crystal optical axis substantially coincides with a light incidence axis (within ± 1°) or substantially 45° (~~allowable~~ within ± 1°)). Furthermore, ~~it is necessary that~~ laser light that ~~can generate~~ generates only a very mono-dispersed wavelength ~~is~~ must be used and a target axis of the lens and an optical axis of the crystal ~~are~~ must be precisely coincided. Accordingly, when, like in a general image pickup device, ~~to the optical axis of the single crystal,~~ natural light (aggregate of lights having various wavelengths) comes in from all directions (angles), ~~the~~this proposal cannot be applied.

~~[0005]~~

~~Patent literature 1: JP No. 2859621~~

~~Patent literature 2: JP-A No. 11-312331~~

~~Non-patent literature 1: S. Nagata, ZUKAI RENDU GA WAKARU HON, pp 56-59, (January 20, 2003), First edition, Third printing~~

~~(NIPPON JITSUGYOU SHUPPAN SHA).~~

~~Disclosure of Invention~~

~~Problems that the Invention is to Solve~~

~~[0006]~~

[0008] ~~That is, lithium~~Lithium tantalate is a material that has ~~the~~ a refractive index of at least 2.0 ~~or more~~ and ~~shows~~ high light transmittance in the visible light region. However, since the birefringence thereof is substantially 0.006, ~~to~~ when light ~~incident~~comes in from various directions, images are duplicated. Accordingly, it has not been used as a lens and optical material.

~~[0007]~~

~~Accordingly, a primary object~~

SUMMARY OF THE INVENTION

[0009] To overcome the problems described above, preferred embodiments of the invention ~~is to~~ provide a high refractive index ~~optical~~lens material that is not affected by ~~an~~ environmental variation ~~and~~ , has high ~~in the~~ visible light transmittance, and has ~~the~~ a birefringence within ± 0.0005, and ~~to~~ provide an optical electronic component ~~therewith~~ and an optical electronic device ~~therewith~~including the same.

~~Means for Solving the Problem~~

~~[0008]~~

[0010] ~~An invention~~ A lens material according to ~~claim 1 is an optical material characterized in that in~~ a preferred embodiment of the present invention includes lithium tantalate having a molar composition ratio (Li_2O/Ta_2O_5) of lithium oxide and tantalum oxide in the lithium tantalate ~~is~~ in the range of 0.975 ~~or more and~~ to 0.982 ~~or less~~, wherein the birefringence of the lithium tantalate is in the range of -0.0005 to 0.0005.

[0011] An ~~invention according to claim 2 is an~~ optical electronic component ~~characterized in that the optical electronic component is formed with~~ according to another preferred embodiment of the present invention is made of the ~~optical~~lens material described ~~in claim 1~~above.

~~An invention according to claim 3 is an optical electronic device characterized in that the optical electronic device contains the optical electronic component formed with the optical material described in claim 1.~~

~~Advantage of the Invention~~

~~[0009]~~

[0012] An optical electronic device according to still

another preferred embodiment of the present invention includes the optical electronic component described above.

[0013] According to preferred embodiments of the present invention, even with lithium tantalate that has a high refractive index and visible transmittance, the birefringence can be confined within a range of ± 0.0005. Thereby, when the lithium tantalate is used as a lens, the same focal distance can be obtained with a larger radius of curvature~~ radius~~. That is, the thickness of the lens can be ~~thinned~~reduced.

~~[0010]~~

[0014] ~~The above objects of the invention, other objects,~~Other features, elements, steps, characteristics and advantages of the present invention will ~~be~~become more ~~clarified~~apparent from the following ~~best modes for carrying out the~~ detailed description of preferred embodiments of the present invention with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

~~[0011]~~

[0015] Fig. 1 is a diagram showing a calibration curve between the Curie temperature and a molar composition ratio.

[0016] Fig. 2 is a diagram showing a relationship between the refractive index and a molar composition ratio.

[0017] —Fig. 3 is a diagram showing a relationship between the respective wavelengths and linear transmittances.

[0018] —Fig. 4 is a sectional view of a planoconvex lens due to an optical material according to a preferred embodiment of the present invention.

[0019] —Fig. 5 is a sectional view of a planoconvex lens due to glass.

[0020] —Fig. 6 is a sectional view of a relay lens system made of convex lenses.

[0021] —Fig. 7 is a sectional view of a relay lens system made of a convex lens and columnar lenses.

~~Reference Numerals~~

~~[0012]~~

~~1: Relay lens~~

~~2: Convex lens~~

~~3: Rod relay lens~~

~~4: Columnar lens~~

~~Best Mode for Carrying Out the Invention~~

~~[0013]~~

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0022] It was ~~found~~discovered that when a single crystal of

lithium tantalate was grown, in the case where a crystal was grown under a particular ratio of lithium oxide and tantalum oxide, the birefringence was reduced, and thereby the present invention ~~came to completion~~was conceived.

~~[0014]~~

[0023] ~~The birefringence~~Birefringence means a difference of refractive indexes of ordinary light and extraordinary light. ~~Since when~~When the difference is large, an image is ~~observed~~ duplicated~~, one that is~~. Thus, a material having a large ~~in the~~ birefringence is difficult to ~~be used~~ use as an ordinary lens.

[0024] On the other hand, when the birefringence is within ± 0.0005, since it is within the error of the refractive index of ordinary light, an image is not ~~observed~~ duplicated.

~~[0015]~~

[0025] In lithium tantalate that is an oxide single crystal, a molar composition ratio (Li_2O/Ta_2O_5) of lithium oxide and tantalum oxide in the lithium tantalate is in the range of 0.975 ~~or more and~~ to 0.982~~ or less~~.

[0026] When the molar composition ratio is less than 0.975 or exceeds 0.982, ~~in some cases,~~ the desired birefringence cannot be obtained.

~~[0016]~~

[0027] When measuring the molar composition ratio of lithium oxide and tantalum oxide, it is ~~usually~~often difficult to quantitatively measure the molar composition ratio ~~at the~~ with a precision of 0.01 ~~according to~~ with a composition analysis. Accordingly, ~~it is desirable to measure~~ the molar composition ratio ~~with~~ is preferably measured using the Curie temperature ~~that~~, which is a physicality value that is sensitive to the molar composition ratio of lithium oxide and tantalum oxide, as an index.

[0028] However, depending on a measurement method of the Curie temperature, the composition may differ. Accordingly, the molar composition ratio ~~in~~according to various preferred embodiments of the present invention means a ratio obtained according to ~~a~~ the measurement method described below.

~~[0017]~~

[0029] The Curie temperature is measured ~~by use of~~preferably using a differential thermal analysis method.

[0030] Measurement conditions are as follows.

- Measurement temperature range: from room temperature to 800°C.
- Temperature rise speed: 20°C/min.
- Gas: air 100 ml/min.
- Measurement vessel: platinum cell.

- Reference sample: platinum.
- Sample amount: 130 mg.
- Temperature calibration: With indium (melting temperature; 156.6°C), tin (melting temperature; 231.97°C), zinc (melting temperature; 419.6°C), aluminum (melting temperature; 660.4°C) and gold (melting temperature; 1064.4°C), from standard melting temperatures and measurement values of melting temperatures, a calibration equation is prepared.
- Standard deviation values as measured temperatures are within 1.0°C.
- A detection amount of Δ(Li/Ta) per 1°C variation of the Curie temperature is 6×10^{-5}.

[0031] A calibration curve between the Curie temperature and a molar composition ratio is shown in Fig. 1.

~~[0018]~~

[0032] Lithium tantalate may ~~contain~~include at least one ~~element~~ of magnesium, zinc and scandium.

[0033] When an optical material made of an oxide single crystal is irradiated with a light source (xenon or halogen lamp) for ~~a long~~ an extended period of time, ~~the~~ coloring ~~due to~~ caused by color centers may ~~be caused.~~ occur. In order to ~~inhibit~~prevent this from occurring, the above-described elements can be added. This is because the oxides do not

substantially show the absorption under the light source.

[0034] —Furthermore, an addition amount thereof is between 0.5 mole percent ~~or more~~ and 10 mole percent~~ or less. The reason why~~. When the addition amount is ~~set at 0.5 mole percent or more is because, when it is~~ less than 0.5 mole percent, an advantage obtained by the addition thereof cannot be sufficiently obtained. The ~~reason why it~~upper addition amount is set at 10 mole percent ~~or less is~~ due to the solid solubility limit.

~~[0019]~~

[0035] ~~—As the~~ The optical electronic components that ~~are~~ may be formed ~~of~~using the ~~optical~~lens material include, for instance, a ~~lens, a~~ light-pickup lens, ~~a prism,~~ an integrator lens~~, a polygon mirror~~ and ~~so on can be cited~~other suitable components.

~~[0020]~~

[0036] —Furthermore, ~~as~~ the optical electronic devices that ~~are~~ may be formed ~~of~~using the optical electronic components include, for instance, an endoscope, a magneto optical disk, a DVD, a liquid crystal projector, a laser printer, a handy scanner, a digital camera and ~~so on can be cited~~other suitable devices.

~~Examples~~

~~[0021]~~

[0037] ~~In what follows, more~~More specific examples of preferred embodiments of the present invention will be described below. However, the present invention is not restricted to ~~the~~these examples.

~~[0022]~~

~~(~~

Example 1~~)~~

[0038] Commercially available raw material powders of 99.99% purity Li_2CO_3 and Ta_2O_5 were used. The raw material powders were weighed at a molar ratio of Li_2CO_3: Ta_2O_5 = 0.55: 0.45 so as to ~~be~~ include a total of 6500 g ~~in total~~ and ~~put into a~~ placed in a Teflon (registered trade mark) vessel, followed by applying dry mixing. After mixing, the mixture was calcined in air at 1300°C for 8 hrs, and thereby, a raw material was prepared. The calcined raw material was ~~filled in a~~ poured into a soft urethane rubber mold and a molded body was prepared under static pressure of 1.96×10^8Pa.

~~[0023]~~

[0039] An Ir (iridium) crucible having an outer ~~form~~dimension of 140 mm, a height of 100 mm and a thickness of 2.0 mm and an Ir cylindrical tube having an outer ~~form~~dimension of 100 mm, a height of 110 mm and a thickness of 1.0 mm were

prepared. The cylindrical tube was inserted so as to coincide with a central axis of the crucible. Inside of the combined crucible (hereinafter, referred to a "double crucible"), the molded body was filled, followed by heating the crucible with high frequency induction heating, and thereby a molten liquid was prepared. After a temperature of the molten liquid was stabilized at a predetermined temperature, with a lithium tantalate single crystal that is cut ~~so~~ such that a longer ~~direction may be in~~ dimension is substantially parallel with an [010] axis as a seed crystal, according to a double crucible method (JP-A-13-287999), a crystal was grown.

~~[0024]~~

[0040] ~~—~~A growing crystal was grown from immediately after the start of the single crystal growth ~~by use of~~using a diameter automatic control system~~so~~, such that a diameter of a straight body portion ~~may be~~ is 50 mm.

[0041] ~~—~~A molar fraction $Li_2O_3/(Li_2O_3 + Ta_2O_5)$ of the raw material molten liquid was maintained in the range of 54.5 to 55.5 mole percent. With a double-structured crucible, a lithium tantalate single crystal having a target composition was pulled up from an inner crucible. While sequentially measuring a weight of a pulling-up single crystal, a weight per unit time (weight growth speed) was obtained. At the weight growth speed,

a raw material having the same composition as the growing single crystal, specifically, a composition where a molar fraction of Li_2O_3/Ta_2O_5 is controlled in the range of 0.975 ~~or more and~~ to 0.982 ~~or less~~ was continuously ~~put in~~provided between the outer crucible and the inner crucible to control the crystal composition precisely, and thereby a single crystal of which birefringence is within a target range was grown.

[0042] —While pulling up a seed crystal at a constant speed for a predetermined time, a molten raw material was solidified. Thereafter, the single crystal was elevated to a predetermined position and cooled over 20 hrs.

~~[0025]~~

[0043] —The obtained single crystal was sandwiched with platinum plates facing in an [001] axis direction of the single crystal and disposed in a resistance heating furnace. This was heated ~~up~~ to 750°C and maintained there ~~sufficiently.~~for a sufficient amount of time. Thereafter, while ~~with the platinum plates as electrodes~~ electricity was flowing at a current density of DC 0.5 mA/cm^2 through the platinum plates, the single crystal was gradually cooled at a speed of 20°C/h to room temperature.

~~[0026]~~

[0044] —The Curie temperature of the obtained single crystal was obtained ~~by means of~~using the foregoing differential thermal

analysis method (TG-DTA (trade name), manufactured by Seiko Instrument) under the foregoing measurement conditions and found to be 661.5°C. When the value was referenced to the calibration curve to obtain the molar composition ratio of lithium oxide and tantalum oxide, ~~the~~ a molar composition ratio of 0.980 was ~~found~~measured.

~~[0027]~~

[0045] —The single crystal was mechanically cut and a wafer (Y-cut wafer) having surfaces vertical to a b axis was prepared. Both surfaces of the wafer were physically mirror polished with a polishing agent to a thickness of 0.5 mm. Thus, a sample according to ~~the~~a preferred embodiment of the present invention was obtained.

[0046] —The sample was measured of the linear transmittance and the refractive index.

~~[0028]~~

[0047] —The refractive index was measured of both surfaces of the wafer at a wavelength of 632.8 nm ~~by use of~~using a prism coupler type refractive index measurement unit (manufactured by Metricon Co., Ltd.).

[0048] —The measurement accuracy of the unit is ± 0.0001 and the measurement resolution power is ± 0.00008.—

[0049] —As a result, the refractive index of ordinary light,

n_o, was found to be 2.1770 ± 0.0002. Since the refractive index of extraordinary light, n_e, was within the resolution power of the measuring unit to n_o, that is, coincided with n_o at $\Delta n = |n_o - n_e| \leq 0.0002$, the single crystal was found to be an optically isotropic material.—

[0050] —Results are shown in Fig. 2.

~~[0029]~~

[0051] —The linear transmittance was measured with a spectrophotometer (trade name: UV-200S, manufactured by Shimadzu Corporation) in a measurement wavelength range of 200 nm to 1700 nm. ~~The linear transmittance was found that an~~An absorption edge was at substantially 260 nm, and in a wavelength range of at least 300 nm~~ or more~~, the absorption coefficient was 0.5 cm^{-1}.

[0052] —Results are shown in Fig. 3.

~~[0030]~~

[0053] —From the foregoing sample, a disk sample having a diameter of 20 mm was cut out and the sample was processed to a planoconvex lens having a front curvature of 50 mm and a rear curvature of infinity. The focal distance thereof was measured and found to be 42 mm (Fig. 4).

[0054] —For comparison, a planoconvex lens having a focal distance of 42 mm was prepared ~~from~~using an optical glass

material BK-7 (borosilicate crown glass, n = 1.51, manufactured by Shot Co., Ltd) and found to have a front curvature of 23 mm (Fig. 5).

[0055] ~~—~~From the above, the thickness of the inventive ~~optical~~ lens material can be ~~thinned in comparison with~~ greatly reduced as compared to glass.

~~[0031]~~

~~(~~

Example 2~~)~~

[0056] ~~—Of~~ The NAs and brightness of a relay lens 1 ~~such as~~ shown in Fig. 6, which is made of only convex lenses 2 that are made of a material according to a preferred embodiment of the present invention (gaps between the respective lenses are made of air), a rod lens relay 3 ~~where~~including a convex lens 2 and columnar lenses 4 that are arranged as shown in Fig. 7 and made of glass (BK-7, n = 1.51), and a rod lens relay 3 ~~where~~including a convex lens 2 and columnar lenses 4 that are arranged as shown in Fig. 7 and are made of a material according to ~~the~~a preferred embodiment of the present invention, ~~the NAs and brightness of the respective optical systems~~and the results were compared. The NA means an effective diameter (aperture diameter) through which an image enters. Furthermore, arrow marks in the drawings show a substance whose image is inverted ~~owing~~due to an imaging

effect.

[0057] ~~—~~In Table 1, based on the relay lens 1 ~~constituted of~~including only the convex lenses 2 shown in Fig. 6, relative numerical values of the rod lens relays 3 made of glass and the material according to ~~the~~various preferred embodiments of the present invention are shown.

~~[0032]~~

~~[~~Table 1~~]~~

	Optical path length	NA	Brightness
Relay lens made of only convex lenses	1.0	1.0	1.0
Glass (BK-7)	0.6	1.5	2.3
Inventive material	0.5	2.2	4.8

~~[0033]~~

[0058] As shown in Table 1, when ~~the inventive material is used as~~ a material according to a preferred embodiment of the present invention is used as the material of the columnar lens 4, in comparison with an ordinary relay lens 1 where the convex lenses 2 alone are used, an optical path length L ~~can be~~ is shortened and the NA ~~can be~~ is increased~~; accordingly~~. Accordingly, the brightness ~~was found~~ is increased in proportion to the refractive index. Thereby, since an effective diameter of the lens can be ~~made smaller~~reduced, in an endoscope for

instance, a diameter of the endoscope can be ~~made smaller; accordingly~~reduced. Accordingly, an endoscope that can be easily operated and ~~alleviate burden~~that reduces stress on a patient can be provided. Furthermore, since two units of the same optical system can be readily arranged, a stereo optical unit can be ~~constituted~~provided, and thereby a detailed three-dimensional image can be observed.

~~Industrial Applicability~~

~~[0034]~~

[0059] ~~An optical~~A lens material according to a preferred embodiment of the present invention can be ~~applied to~~used for a lens and the lens can be ~~applied to~~ used in an optical electronic component.

[0060] While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.